Use Attainability Analysis of Inland Rivers and Streams in the Eastern Lower Mississippi River Alluvial Plains Ecoregion for Review of Dissolved Oxygen Water Quality Criteria

Prepared by the

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June 7th, 2013

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Executive Summary

The current dissolved oxygen criterion for most streams in the eastern Lower Mississippi River Alluvial Plains (LMRAP) ecoregion is a year-round, one-day minimum of 5 mg/L for inland areas and 4 mg/L for estuarine areas; these criteria are based on the national recommendations for warm-water fishes. However, based on a previous study conducted by the Louisiana Department of Environmental Quality (LDEQ) in the western portion of this ecoregion (i.e., the Barataria-Terrebonne Use Attainability Analysis), it is likely that this criterion is not attainable for streams in this area of the state throughout the year. As in the Barataria-Terrebonne Use Attainability Analysis, it may be appropriate to establish a criterion of lower magnitude during the time frame in which high temperature, low flow, limited mixing, and low rainfall conditions result in the maximum extent of biochemical, oxygen-demanding activities and ultimately naturally low dissolved oxygen concentrations (i.e., the critical period). This use attainability analysis re-evaluates the dissolved oxygen criterion and the critical period in the eastern portion of the LMRAP ecoregion based on a qualitative and quantitative ecological comparison with the western portion of the ecoregion in which criteria and critical period refinements have already been well-established.

Physical, chemical, and biological data from both eastern and western portions of the ecoregion were collected between 2005 and 2012 through various department-led projects (including the Barataria-Terrebonne Use Attainability Analysis). Twelve least-impacted stream sites, located in both the eastern and western portions of the LMRAP, were selected for use in the study; data from these sites were compared to verify ecological similarity. Statistical comparisons were made for dissolved oxygen concentrations, while more general comparisons were made for other water quality parameters as well as for habitat observations and fish community measurements.

Similarities were observed between eastern and western portions of the LMRAP in dissolved oxygen, pH, dissolved oxygen percent saturation, temperature, inorganic/organic content composition, fish species richness, and fish total abundance; no noteworthy dissimilarities were observed. Critical period determinations were similar in the eastern and western LMRAP, with dissolved oxygen concentrations falling below 5 mg/L in most months of the year. These similarities, as well as a re-calculation of the criterion using only eastern data, suggest that the criteria established for streams in the western portion of the LMRAP in the Barataria-Terrebonne Use Attainability Analysis are appropriate for the eastern portion as well. Therefore, LDEQ proposes a one-day minimum criterion of 2.3 mg/L between the months of March to November in the eastern portion of the LMRAP. No changes are proposed at this time for the eastern LMRAP between the months of December to February; a one-day minimum criterion of 5.0 mg/L in inland areas and 4 mg/L in estuarine areas will still apply except where site-specific criteria have been established.

1. Introduction

Louisiana was required by the U.S. Environmental Protection Agency (USEPA) to establish a statewide dissolved oxygen criterion of 5 mg/L for inland and open ocean waters as a one-day minimum to protect the early life stages of warm water fishes; 4 mg/L was adopted for estuarine areas. These criteria were based on the nationally recommended criteria as documented in USEPA's memo to the Louisiana Stream Control Commission (USEPA, Busch to Lafleur 1972;) and in *Quality Criteria for Water,* EPA 440/5-86-001, commonly referred to as The Gold Book (USEPA 1986). However, since the 1980's it has been documented (through site-specific studies) that many of Louisiana waters that support fish and wildlife propagation do not meet the present statewide criteria either on a daily basis and/or on a seasonal basis due to local ecology. Low flow (and therefore low aeration potential and high residence times) combined with substantial amounts of allochthonous organic material, results in naturally low dissolved oxygen conditions in many areas of the state. While LDEQ has been updating criteria on a site-specific basis through site-specific Use Attainability Analyses (UAAs), LDEQ has also initiated the use of an ecoregion approach to establish more regionally appropriate dissolved oxygen criteria (DeWalt 1995; DeWalt 1997; LDEQ 1996).

A UAA, referred to as the Barataria-Terrebonne UAA (BTUAA), was conducted in 2008 to determine the appropriate dissolved oxygen criteria for all water body types in the portion of the Lower Mississippi River Alluvial Plains (LMRAP) ecoregion west of the Mississippi River (LDEQ 2008a). The analysis yielded criteria changes in 60 subsegments total, with changes in 20 rivers and streams subsegments, to a minimum criterion of 2.3 mg/L during the critical season (i.e., March through November). Due to resource limitations, LDEQ was not able to include any data from the portion of the LMRAP east of the Mississippi River in the study; therefore, the statewide dissolved oxygen criteria of 5 mg/L (inland) and 4 mg/L (estuarine) remains in this area of the state, except where site-specific criteria have been established (LAC 33:IX.1123.Table 3).

This UAA serves as a continuation of the BTUAA effort and will evaluate the appropriate dissolved oxygen criteria for the eastern portion of the LMRAP. According to the ecoregion concept, the eastern and western portions of this ecoregion are expected to be ecologically similar with similar water quality conditions; however, LDEQ did not previously have the data to verify this similarity. The objectives of this analysis are to (1) demonstrate the ecological similarity (or dissimilarity) between eastern and western portions of the LMRAP, (2) establish appropriate critical and non-critical periods for the eastern LMRAP, and (3) provide criteria recommendations for the eastern LMRAP.

LDEQ has collected chemical, physical, and biological data in both portions of the LMRAP and will compare the two areas both qualitatively and quantitatively. If similarity between the eastern and western portions of the LMRAP is confirmed, then LDEQ will continue the criteria revisions from the western portion (from the BTUAA) into the eastern portion. If similarity is not confirmed, then criteria will be developed for the eastern portion of the LMRAP, independently of the western portion, using the protocols established in the Memorandum of Agreement (MoA) between EPA R6 and LDEQ (LDEQ 2008b).

2. Methods

2.1 Study Area

The LMRAP ecoregion is a low-lying area of the state located to the east of the Atchafalaya River levee system and to the north of the Intracoastal Waterway (Figure 1; LDEQ 2013). Vegetation includes oak, tupelo, bald cypress and bottomland hardwood forests. Land use consists of cropland, grazing land, pasture, woodland, marsh, wetland, and forest (Figure 2). Many of the streams in this ecoregion have been hydrologically modified (LDEQ 1992).

This ecoregion is bisected by the Mississippi River; the portion located to the west of the Mississippi River (i.e., the western "subecoregion") was addressed in the BTUAA, while the portion located to the east of the Mississippi River (i.e., the eastern "subecoregion") will be the focus of this UAA.

Figure 1. Water Quality Standards Ecoregions for Louisiana. Delineations include 2013 refinements.

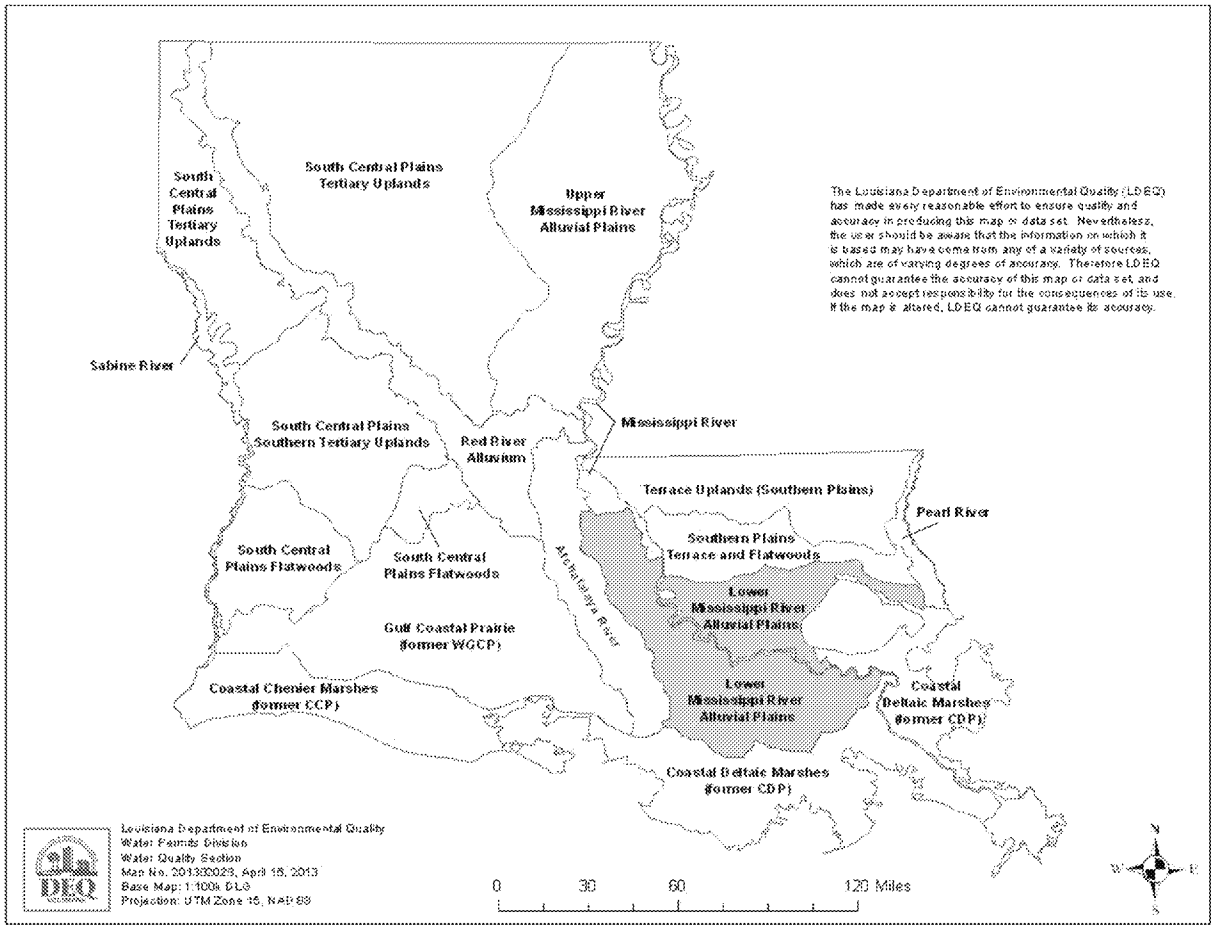
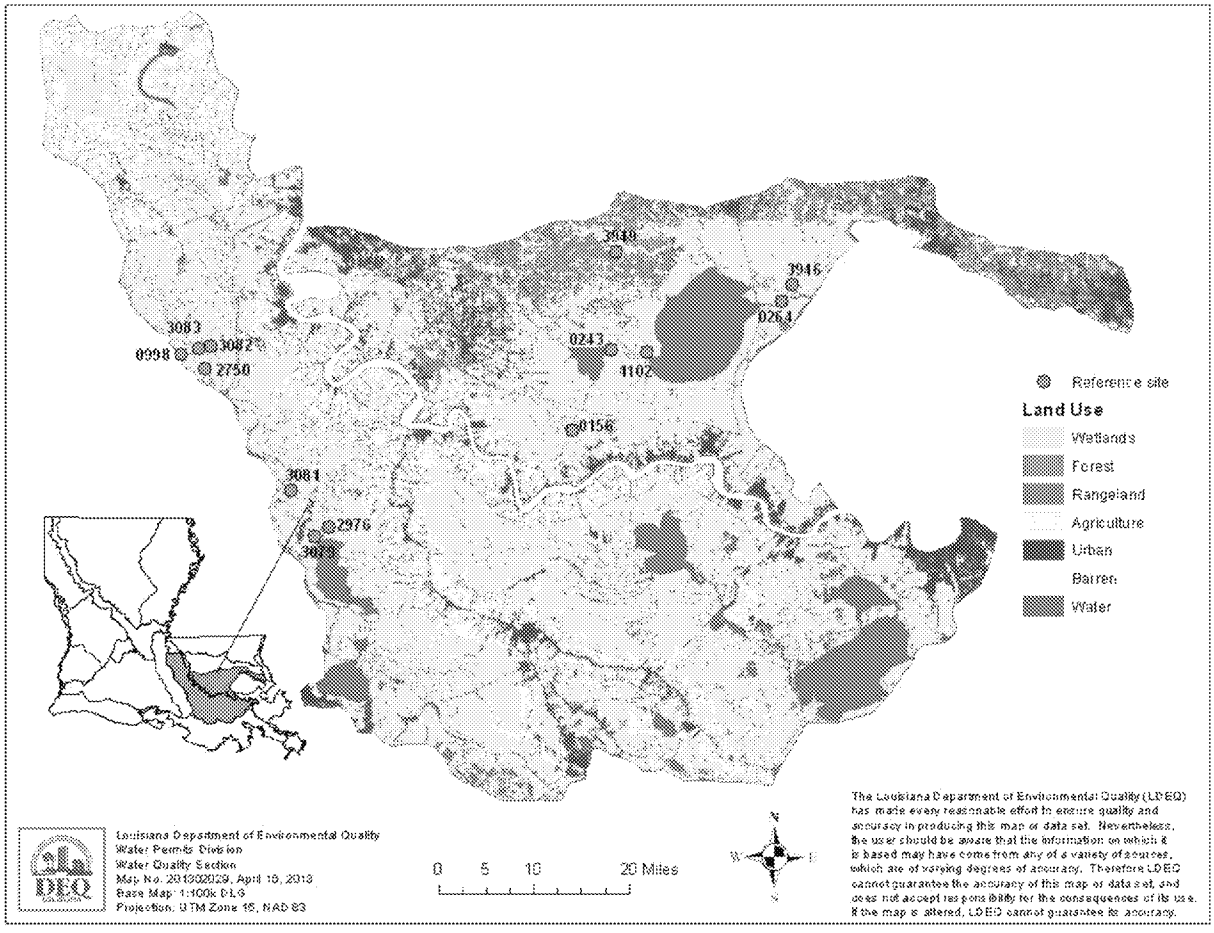


Figure 2. Least-impacted sites and land use in the LMRAP ecoregion. Land use based on USGS data from 1998.



2.2 Study Sites

To identify least-impacted sites, several different sources of information were used including, but not limited to, the following: land use maps, aerial photography, salinity maps, hydrological studies, waterbody maps, point source inventories, local expertise, and reconnaissance surveys. These tools were used to identify and verify sites that are least-impacted relative to the conditions of the LMRAP ecoregion in accordance with the MoA between EPA R6 and LDEQ (LDEQ 2008b). The same protocols were used to select least-impacted sites in the western and eastern subecoregions (LDEQ 1996; LDEQ 2007; LDEQ 2008a; LDEQ 2008b).

Field reconnaissance surveys were conducted in 2005 and in 2012 for sites in the western LMRAP and in 2009, 2010, and 2012 for sites in the eastern LMRAP. During the surveys, the condition of potential least-impacted streams was documented with field notes and photographs.

Based on review of the available data and reconnaissance visits to the areas, LDEQ identified thirteen least-impacted sites in the LMRAP ecoregion (Table 1). Locations of least-impacted sites are shown in Figure 2. All sites were considered "least-impacted" by anthropogenic influences relative to the characteristics of the ecoregion.

2.3 Data Collection

Data collection efforts for the refinement of dissolved oxygen criteria in streams began in the western LMRAP in 2005 with the BTUAA (see LDEQ 2007 for project plan). Several waterbody types (i.e., streams, lakes, canals, and bays) and a second ecoregion (i.e., the Coastal Deltaic Marshes) were also included in this study. A total of 26 least-impacted sites were sampled between 2005 and 2008 as part of this effort; eight of these sites were stream sites in the western LMRAP subecoregion. In 2010, sampling resumed in the eastern LMRAP and the eastern CDM subecoregions under a similar monitoring design with limited *in situ* water quality sampling in the western subecoregions (see LDEQ 2010a for project plan). Sampling was interrupted in April 2010 by the oil spill in the Gulf of Mexico. In 2012, the scope of the project was limited to dissolved oxygen refinements of streams in the eastern LMRAP with a focus on verification of eastern and western similarities (see LDEQ 2012 for project plan). Six least-impacted sites were selected within each subecoregion for sampling. Specific methods for chemical, physical, and biological sampling are provided below.

2.3.1 Chemical Data

LDEQ collected continuous monitoring water quality data from May 2005 to February 2008 at eight stream sites in the western LMRAP as part of the BTUAA, from January to May 2010 at the same sites as well as eight sites in the eastern LMRAP, and again from March to December 2012 at six stream sites in both the eastern and western LMRAP (Appendix A). Water quality measurements included dissolved oxygen (mg/L), temperature (°C), pH, specific conductivity (µS/cm), salinity (ppt), and percent dissolved oxygen (% saturation). Continuous monitors were deployed for 24 to 72 hours to collect diurnal data.

Table 1. LDEQ least-impacted sampling sites for the Lower Mississippi River Alluvial Plains ecoregion.

Section	LDEQ Site Number	Site Name	Subsegment	Water Body Type	UTM E	UTM N
Eastern	3949	Tickfaw River	LA040502	STREAM	725188.02	3363873.70
	0243	Blind River east of Gonzales, LA	LA040403	STREAM	725017.19	3345754.54
	3946	Middle Bayou near Manchac, LA	LA040601	STREAM	754850.78	3356552.46
	0156	Blind River at Gramercy, LA	LA040403	STREAM	718531.00	3332180.00
	1102	Blind River near confluence with Lake Maurepas	LA040401	STREAM	731015.00	3345239.00
	0264	Pass Manchac at Manchac, LA	LA040601	STREAM	753911.26	3354016.70
Western	0998	Upper Grand River at Levee	LA120107	STREAM	652119.91	3344918.65
	3083	Upper Grand River NE of Grand River, LA	LA120107	STREAM	655242.00	3345966.00
	3081	Bay Natchez west of Bayou Corne, LA	LA120201	STREAM	670839.00	3321836.00
	2976	Grand Bayou southwest of Belle Rose, LA	LA120206	STREAM	677280.00	3315683.00
	3079	Pierre Part Bay southeast of Pierre Part, LA	LA120204	STREAM	674905.00	3314009.00
	2750	Pat Bay southwest of Plaquemine, LA*	LA120107	STREAM	656190.82	3342574.57
	3082	Lower Flat of the Upper Grand River northeast of Grand River, LA	LA120107	STREAM	657166.00	3346302.00

* Site 2750 in western LMRAP replaced with site 0998 in July 2012 due to accessibility issues.

All water quality sampling was performed using protocols described in LDEQ's Standard Operating Procedures for water quality sampling (LDEQ 2010b) and according to the Quality Assurance Project Plans (QAPPs) for the BTUAA (LDEQ 2007) and for the Evaluation of Aquatic Life Uses and Dissolved Oxygen and Nutrient Criteria in Louisiana's Ecoregion Streams (LDEQ 2009). Anomalous data points were noted and excluded as appropriate (Appendix A). Non-detects were qualified as estimates and set equal to the detection limit of 0.2 mg/L (conservative approach when setting minimum-based criteria).

2.3.2 Physical Data

LDEQ adapted the Low Gradient Stream Habitat Assessment form from USEPA's Rapid Bioassessment Protocols (Barbour et al. 1999) for use in the BTUAA (LDEQ 2007). This form was used to provide guidelines for a qualitative, visual-based assessment of the habitat quality and stream characteristics of Louisiana low gradient streams. Modifications to the form were made in 2010 (Figure 3).

Habitat assessments were conducted by LDEQ at least-impacted stream sites in the LMRAP ecoregion from May 2005 to February 2008, January 2010 to May 2012, and March to December 2012. In these assessments, key parameters (e.g., local watershed erosion and nonpoint source pollution; proportion of organic and inorganic streambed substrate; stream velocity; instream cover and substrate composition; channel morphology; and riparian and bank structure) were identified to provide a consistent assessment of habitat quality. Other qualitative measurements were estimated by LDEQ field staff for the following variables: predominant surrounding land use, canopy cover, hydromodifications, accessibility, recreational activities, water clarity and color, and percent composition of inorganic and organic substrate. Observations were recorded on the LDEQ Habitat Assessment forms.

Habitat assessments were completed for all sites. This information was used to verify or revoke the least-impacted site status of an area (i.e., ensure that all site selection criteria are still met during the sampling timeframe) as well as make qualitative comparisons between the eastern and western subecoregions. Site information and survey conditions were documented during each sampling event using LDEQ's Site Information form (LDEQ 2009).

2.3.3 Biological

LDEQ fish sampling occurred between 2005 and 2006 in the western subecoregion as part of the BTUAA and during 2010 and 2012 in both subecoregions as part of LDEQ's continuing efforts in this ecoregion. A total of 10 least-impacted stream sites were sampled during this time period. Fish data were collected between the months of March and October, primarily using electroshocking and hoop nets with limited seining. Collection methods were consistent with protocols implemented in previous Louisiana ecoregion studies (DeWalt, 1995; DeWalt, 1997; LDEQ, 1996; LDEQ, 2009). Fish data was used to calculate species richness, total abundance, and species relative abundance.

Figure 3. Habitat Assessment Form for Low Gradient Streams (adapted from Barbour et al. 1999). Version modified in 2010.

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Site Number: _____ Water Body Name: _____ Parish: _____ Date: ___/___/___ Time: ___:___ hrs

Locality: _____ Subseg: _____ Project Number: _____ Completed By: _____

Weather Conditions: _____

Predominate Surrounding Land Use (circle): Forest Field/Pasture Agriculture Residential Industrial

Other: _____

Local Watershed Erosion (circle): None Slight Moderate Heavy Comments: _____

Stream Surface Shading (Foliar Nonfoliar) (circle):
Open Mostly Open/Partly Shaded Mostly Shaded/Partly Open Shaded **Estimate of Percent Cover**_____%

Dam Present? (circle): Yes No **Specify if manmade or natural (i.e. beaver dam):** _____ _____
Specify any dates or other markings on dams or bridges: _____

Channelized (circle): Yes No **Specify if dredged or natural channelization present:** _____

Access is provided by (circle): Road Trail Park Urban/Suburban Location Beach Boat Ramp Dock/Raft Bridge

Is Access Impaired by (circle if applicable): Enclosure/Fence Private Property Other: _____

Evidence of recreational use (circle): Swimmers Fishermen Boaters Rope Swings Fishing Tackle
Other: _____

Approximate the following:
Width (m): _____ **to** _____, **Stream Velocity (m/sec):** _____,
Riffle Depth (m): _____, **Run Depth (m):** _____, **Pool Depth (m):** _____, **High Water Mark (m):** _____.

Water Quality: (Do the following if a Hydrolab is available for field/in-situ readings): **Instrument used:** _____

Turbidity (circle): Clear Slightly Turbid Opaque **Water Color:** _____

Temp (C): _____, **D.O. (mg/L)** _____, **pH** _____, **Conductivity (µmhos/cm)** _____, **Salinity (ppt)** _____,
D.O. % _____, **Battery** _____.

Other Data Collection: Was *Fish Data Collected?* *Yes* *or* *No*

Observations: _____

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Site Number: _____ Water Body Name: _____ Parish: _____ Date: ___/___/___ Time: ___:___ hrs

Locality: _____ Subseg: _____ Project Number: _____ Completed By: _____

Inorganic Substrate Components			Organic Substrate Components		
Substrate Type	**Characteristics**	**% Composition**	**Substrate Type**	**Characteristics**	**% Composition**
Gravel	Can be held between thumb and forefinger		**Detritus**	Sticks, wood, leaves (CPOM)	
Sand	Gritty, too small to pick up individually		**Muck–Mud**	Black, very fine organic (FPOM)	
Silt	Too small to pick up individually		**Marl**	Gray, shell fragments	
Clay	Slick, may be molded with hands		**Other**	Organic or Inorganic	

Figure 3. Continued.

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Site Number: _____ Water Body Name: _____ Parish: _____ Date: ___/___/_____ Time: ___:___

Locality: _____ Subseg.: _____ Project Number: _____ Completed By: _____

Directions: Give an accurate description of a typical portion of the waterway. Circle best category for each parameter, if non-typical of any of these or a mix of 2 or more parameters, explain in comments row.

Habitat Parameter					
1. Bottom Substrate / Instream Cover	Abundant cover. Frequent submerged logs, snags, aquatic vegetation, and undercut banks.	A good mix of submerged logs, snags, and instream and overhanging vegetation.	Some logs and snags and/or occasional areas of instream or overhanging vegetation.	Only slight cover. Stream is mostly cleared, with occasional snags and very little instream / overhanging vegetation.	Lack of habitat predominate. No cover, snags or vegetation. No undercut banks.
Circle rating	19 18 17 16	15 14 13 12	11 10 9 8	7 6 5 4	3 2 1 0
Comments					
2. Pool/ bottom substrate characterization	Mainly firm sand and/or gravel.	Mixture of soft sand, mud and/or clay.	All mud or clay.	All clay or mixture of silt and clay.	Top layer, all silt.
Circle rating	19 18 17 16	15 14 13 12	11 10 9 8	7 6 5 4	3 2 1 0
Comments					

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Site Number: _____ Water Body Name: _____ Parish: _____ Date: ___/___/_____ Time: ___:___

Locality: _____ Subseg.: _____ Project Number: _____ Completed By: _____

Habitat Parameter					
3. Channel Sinuosity (use a map & measure stream using a string, then divide by the straight line distance)	Greater then four times straight-line distance.	Three to four times straight-line distance.	Two to three times straight-line distance.	One to two times straight-line distance.	Channel straight, channelized waterway.
Circle rating	14 13 12	11 10 9	8 7 6	5 4 3	2 1 0
Comments					
4. Bank vegetative stability	Over 90% of streambank surfaces covered by vegetation	80 – 90% of streambank surfaces covered by vegetation	65 – 80% of streambank surfaces covered by vegetation	50 – 65% of streambank surfaces covered by vegetation	Less then 50% of streambank surfaces covered by vegetation
Circle rating	4	3	2	1	0
Comments					

Figure 3. Continued.

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Site Number: _____ Water Body Name: _____ Parish: _____ Date: ___/___/___ Time: ___:___

Locality: _____ Subsec.: _____ Project Number _____ Completed By: _____

Habitat Parameter					
5. Streamside cover	Dominant vegetation is a mixture of shrubs, trees and native vegetation	Dominant vegetation is of shrub form	Dominant vegetation is of tree form	Dominant vegetation is grass and forbes	Over 50% of streambank have no vegetation and is predominately soil, sand and/or concrete.
Circle rating	4	3	2	1	0
Comments					
6. Riparian vegetative zone width	Streamside vegetation on both sides > 50 m.	Streamside vegetation on both sides > 25 m.	Streamside cover on one side is > 10 m with the other side having at least 5 m of cover	Streamside cover on one side is > 10 m	Neither side has over 10 m of streamside cover
Circle rating	4	3	2	1	0
Comments					

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Site Number: _____ Water Body Name: _____ Parish: _____ Date: ___/___/___ Time: ___:___

Locality: _____ Subsec.: _____ Project Number: _____ Completed By: _____

Habitat Parameter					
7. Bank stability	Stable, no signs of erosion, no undercutting of banks	Stable, spot erosion occurring infrequently, little undercutting of banks	Localized erosion evident, no continuous damage to bank structure	Unstable, extensive areas of bare banks, Significant erosion evident	Very unstable, over 50% of the banks have some form of erosion
Circle rating	4	3	2	1	0
Comments					

OVERALL SCORE: _____

SCORER (Print Name): _____

2.4 Data Analysis

2.4.1 Eastern and Western Subecoregion Comparisons

To determine if the eastern and western subecoregions of the LMRAP are ecologically similar (or dissimilar), chemical, physical, and biological data were compared between the eastern and western subecoregions both qualitatively and quantitatively. Site medians were calculated for relevant chemical, physical, and biological quantitative parameters and were compared between eastern and western sites. Also, a series of statistical tests were used to compare dissolved oxygen concentrations between the subecoregions. Prior to all statistical tests, data were truncated to increments of 24 hours.

First, all dissolved oxygen data collected in 2012 were aggregated by site via averaging and a t-test was performed to compare the 6 sites in the eastern subecoregion with the 6 sites in the western subecoregion (degrees of freedom = 10). A second statistical test was performed in which all data was aggregated by sampling event (and not site) via averaging to compare the 38 sampling events in the eastern subecoregion with the 35 sampling events in the western subecoregion (degrees of freedom = 71). The third statistical test was a t-test based only on data collected between 6 am and 12 pm during the critical period determined in the BTUAA (March-November) with data aggregated by site via averaging (degrees of freedom = 10). This time period was selected because it is the time period that was used to determine criteria in the BTUAA. The fourth statistical test was a t-test based only on data collected between 6 am and 12 pm during the critical period determined in the BTUAA (March-November) with data aggregated by event via averaging (degrees of freedom = 59). [Note: parametric t-tests were used since populations were found to be normally distributed based on a Shapiro-Wilk test; however, analogous non-parametric tests (Wilcoxon rank-sum test) were also performed and yielded the same conclusions.]

2.4.2 Determination of Critical Period in the Eastern Subecoregion

To identify the critical period for the eastern subecoregion, dissolved oxygen continuous monitoring data collected in 2010 and 2012 from this subecoregion were graphically displayed by month of collection. Values were compared to the national benchmarks of 5mg/L and 4mg/L for freshwater, estuarine, and marine waters. In accordance with the protocols outlined in the MoA, the month when data points for dissolved oxygen fell below the national benchmark marked the beginning of the critical period, while the month when data points for dissolved oxygen no longer fall below the national benchmark marked the ending of the critical period (LDEQ 2008b).

2.4.3 Calculation of a Dissolved Oxygen Criterion for the Eastern LMRAP

If ecological similarity between the eastern and western subecoregions could be verified, then no criteria calculations would be necessary. However, as a potential option for criteria refinements if ecological similarity between the two subecoregions could not be verified, a dissolved oxygen criterion was calculated for the eastern LMRAP. Using the protocols established in the MoA between EPA R6 and LDEQ (LDEQ 2008b), dissolved oxygen continuous monitoring data

collected in the eastern LMRAP subecoregion was truncated to exclude all data points not collected between 6 am and 12 pm. This is the typical time range in which the dissolved oxygen minimum occurs in most waters. Datasets were aggregated by critical/non-critical period, and the 10th percentile was calculated for each dataset as a potential criterion for this area.

3. Results and Discussion

3.1 Eastern and Western Subecoregion Comparisons

In 2012, over 11,000 dissolved oxygen continuous monitoring records were collected in the eastern subecoregion of the LMRAP and over 9,000 records were collected in the western subecoregion. The distributions of data in each subecoregion were highly overlapping (Figures 4 and 5) and mean dissolved oxygen was not significantly different between the eastern and western subecoregions of the LMRAP in any of the statistical tests performed (Table 2). [Note: Since both populations were normally distributed (Shapiro-Wilk test, $p < 0.05$), a parametric t-test was used; however, an analogous non-parametric test (Wilcoxon rank-sum test) was also performed and yielded the same conclusions.]

Other water quality parameters were similar between the two subecoregions as well (Table 3); overlapping ranges of pH, dissolved oxygen saturation, and temperature were observed. Habitat and biological parameters were also similar between the two subecoregions. Both subecoregions typically had high (greater than 90%) inorganic content composition, low (less than 40%) organic content composition, high (greater than 90%) silt/clay composition, low (less than 10%) sand composition, and low to medium (10% to 40%) levels of detritus (Table 3). Species richness ranged from 10 to 24 taxa in the western subecoregion and from 12 to 19 taxa in the eastern subecoregion. Total abundance ranged from 129 to 423 individuals in the western subregion. This parameter was more variable in the eastern subecoregion due to one site (0264, Pass Manchac); once excluded, the range in the eastern subecoregion was 239 to 462 individuals (Table 3). A more detailed analysis of habitat, chemical and biological parameters can be found in Appendix B, C, and D, respectively.

Figure 4. Distribution of all dissolved oxygen data collected in 2012 in the eastern and western subecoregions of the LMRAP. Data are presented as cumulative distribution functions.

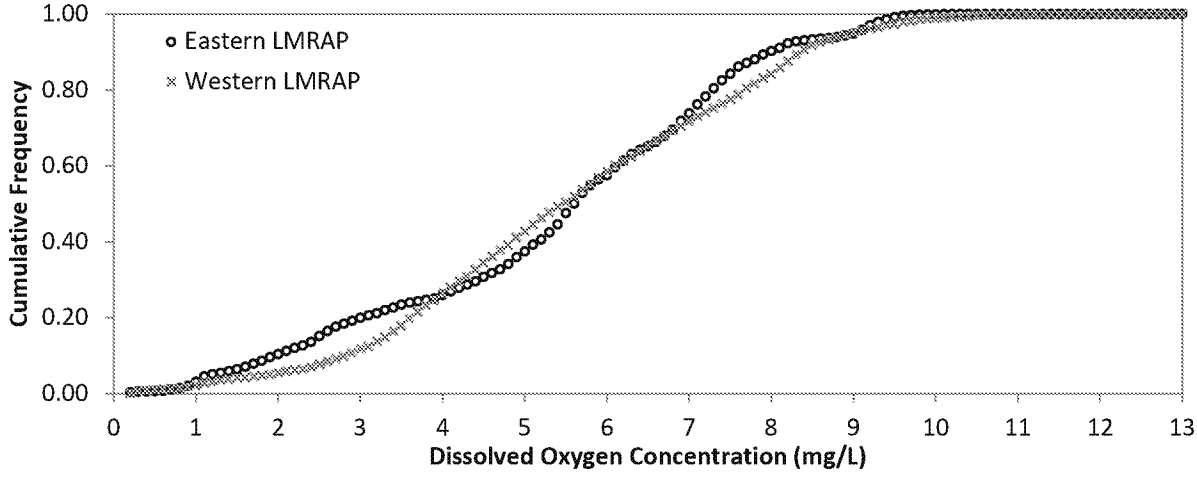


Figure 5. Distribution of dissolved oxygen data collected in 2012 in the eastern and western subecoregions of the LMRAP. Data were truncated by time of day (6 am to 12 pm only) and season (critical period only) and are presented as cumulative distribution functions.

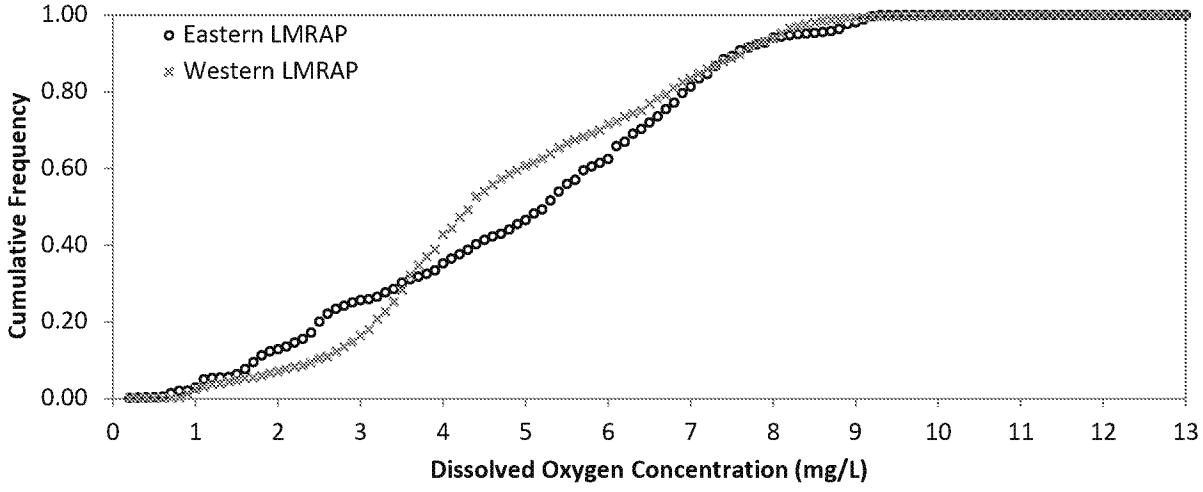


Table 2. Summary of statistical tests to compare dissolved oxygen concentrations in the eastern and western subecoregions of the LMRAP.

Test	Data Truncation		Aggregation Unit	Degrees of Freedom	Eastern Average	Western Average	P-value
	By Time of Day	By Month					
1	24 hour periods	None	Site	10	5.3	5.5	0.78
2	24 hour periods	None	Event	71	5.3	5.4	0.87
3	6 am to 12 pm only	Critical Period Only	Site	10	4.8	4.7	0.95
4	6 am to 12 pm only	Critical Period Only	Event	59	4.9	4.6	0.61

Table 3. Summary of physical, chemical, and biological characteristics at least-impacted sites in the LMRAP ecoregion. Values include data collected between 2005 and 2012 and represent the median of multiple collections at each site.

		Western Subecoregion						Eastern Subecoregion					
	Site	Upper Grand River at Levee	Grand Bayou southwest of Belle Rose	Pierre Part Bay southeast of Pierre Part	Bay Natchez west of Bayou Corne	Lower Flat of the Upper Grand River northeast of Grand River	Upper Grand River NE of Grand River	Blind River at Gramercy	Blind River east of Gonzales	Pass Manchac at Manchac	Blind River near confluence with Lake Maurepas	Middle Bayou near Manchac	Tickfaw River
	LDEQ Site Number	**0998**	**2976**	**3079**	**3081**	**3082**	**3083**	**0156**	**0243**	**0264**	**1102**	**3946**	**3949**
Physical[1]	% inorganic material in sediment	NA[3]	90	95	NA[3]	NA[3]	NA[3]	60	90	NA[3]	95	NA[3]	70
	% organic material in sediment	NA[3]	10	5	NA[3]	NA[3]	NA[3]	40	10	NA[3]	5	NA[3]	30
	% silt/clay in inorganic component	100	10	90	90	100	100	90	92.5	100	92.5	100	82.5
	% sand in inorganic component	0	90	10	10	0	0	10	7.5	0	7.5	0	15
	% detritus in organic component	20	10	0	0	20	20	25	32.5	5	22.5	17.5	40
Chemical	pH of water	7.43	7.22	7.915	7.51	7.47	7.5	6.75	6.76	7.27	6.88	6.35	6.3
	Specific conductivity of water	301	260	309	399	337	341	311	222	1877	231	2228	45
	% DO (or % saturation) in water	64	46.6	85.15	69.6	71	70.6	37.2	54.4	93	66.8	56.3	72.5
	Water temperature	25.24	26.215	25.8	25.6	26.89	25.01	23.78	23.46	24.14	23.57	24.11	21.65

		Western Subecoregion						Eastern Subecoregion					
	Site	Upper Grand River at Levee	Grand Bayou southwest of Belle Rose	Pierre Part Bay southeast of Pierre Part	Bay Natchez west of Bayou Corne	Lower Flat of the Upper Grand River northeast of Grand River	Upper Grand River NE of Grand River	Blind River at Gramercy	Blind River east of Gonzales	Pass Manchac at Manchac	Blind River near confluence with Lake Maurepas	Middle Bayou near Manchac	Tickfaw River
	LDEQ Site Number	**0998**	**2976**	**3079**	**3081**	**3082**	**3083**	**0156**	**0243**	**0264**	**1102**	**3946**	**3949**
Biological	Species richness	15[2]	20	12[2]	10[2]	15[2]	23.5	19	16	12.5	14.5	11.5	18.5
	Total abundance	118[2]	141	169[2]	129[2]	205[2]	423	283	238.5	2271.5	239.5	461.5	373.5

1 Median physical characteristic values calculated from 2010/2012 habitat assessments only.

2 Median biological characteristics based on external data sources (LDWF and EPA) as reported in the BTUAA (LDEQ 2008a).

3 Data not available

3.2 Determination of Critical Period

In the BTUAA, dissolved oxygen in the western LMRAP fell below the national benchmarks of 5 and 4 mg/L during all months except February (Figure 6). Although dissolved oxygen did drop below the benchmarks in January and December, given the temperature observed in these months (less than 16°C) and potential timing of fish spawning (see LDEQ 2008a), these months were not considered to be part of the critical period. Thus, the critical period was determined to be March through November for streams in the western LMRAP ecoregion; the non-critical period was determined to be December through February.

Dissolved oxygen in the eastern LMRAP also fell below the national benchmarks of 5 and 4 mg/L throughout the year (Figure 7). Based on the scientific rationale used in the BTUAA, the critical period for streams in the eastern LMRAP ecoregion will also be March through November; the non-critical period will be December through February.

Figure 6. Critical period determination made in the BTUAA for streams in the western LMRAP ecoregion (LDEQ 2008a).

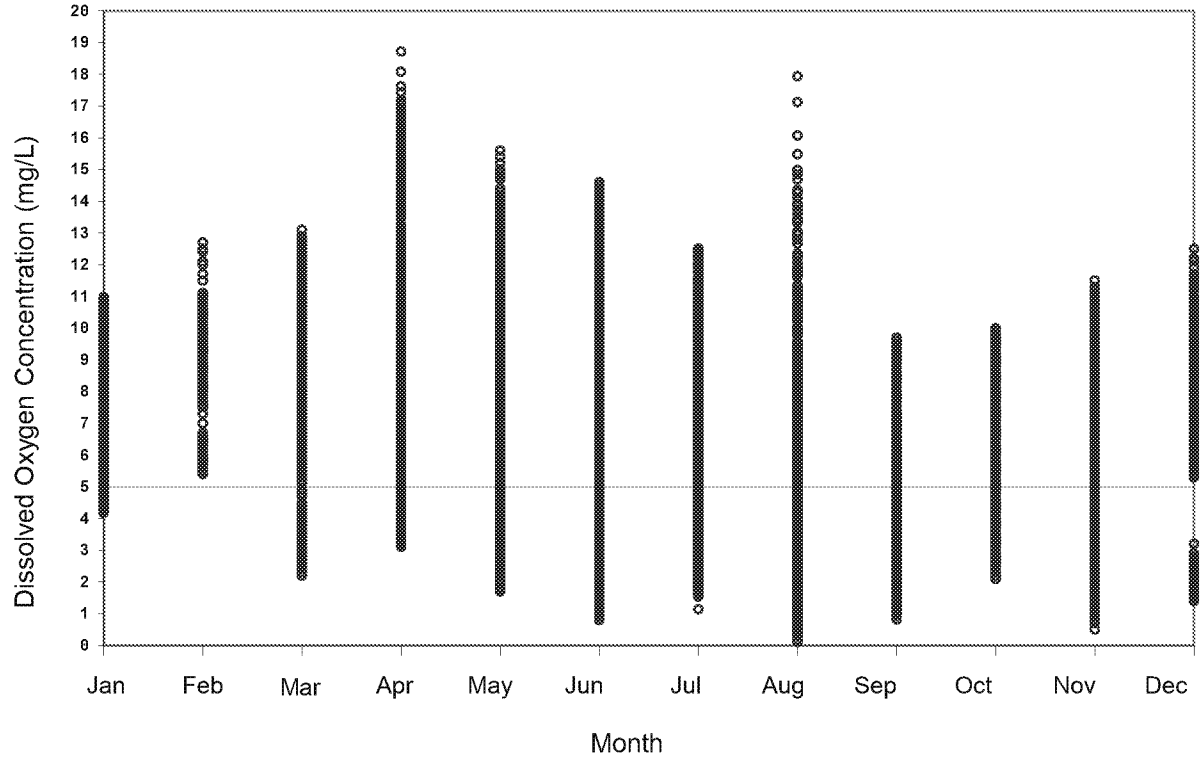
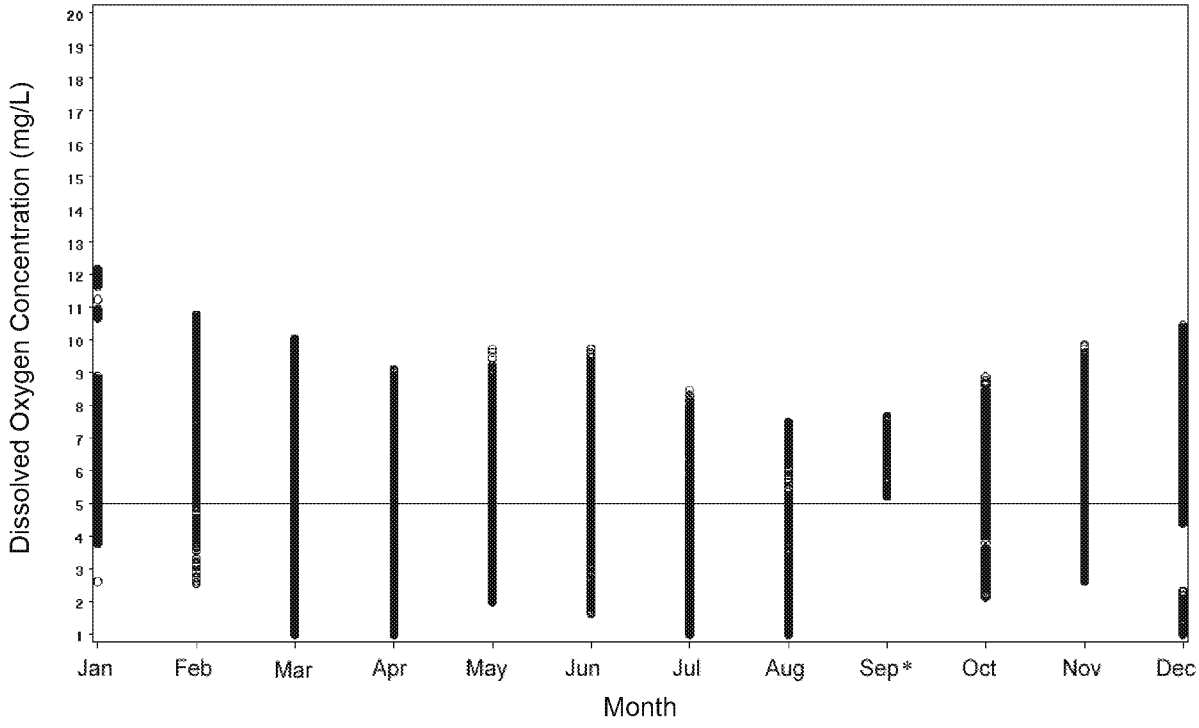


Figure 7. Critical period determination for the eastern LMRAP ecoregion.



* sampling activities in September 2012 were interrupted by Hurricane Isaac.

3.3 Criteria Determination

Based on both qualitative and quantitative comparisons of the eastern and western subecoregions of the LMRAP, ecological similarity was verified (i.e., no apparent or statistically significant differences were observed between the two subecoregions). Therefore, the criteria established for streams in the BTUAA in the western subecoregion are also appropriate for streams in the eastern subecoregion. LDEQ proposes that stream criteria for dissolved oxygen be revised with the values established in the BTUAA (2.3 mg/L; see LDEQ 2008a). Proposed revision of dissolved oxygen criteria for streams in the eastern LMRAP are presented in Table 4.

A post-hoc calculation of the 10th percentile of data collected in the eastern LMRAP between 6 am and 12 pm (per MoA and BTUAA protocols) yielded values slightly lower than the proposed criteria revisions and therefore support the use of the BTUAA criteria in the eastern LMRAP. However, caution should be taken if using these values independently of the BTUAA findings because they are based on one year of data collection. The proposed critieria revisions are also supported by the findings of Justus et al. (2012) in which they observed fish community changes at a dissolved oxygen concentration of 2.3 mg/L.

Table 4. Proposed criteria revisions for streams in the eastern LMRAP and comparisons to the current criteria.

Period	Current Criteria	BTUAA Criteria	Recommended Criteria
Critical Period (March – November)	5.0 mg/L (inland) 4.0 mg/L (estuarine)	2.3 mg/L (all streams)	2.3 mg/L (all streams)
Non-Critical Period (December – February)	5.0 mg/L (inland) 4.0 mg/L (estuarine)	5.0 mg/L (inland) 4.0 mg/L (estuarine)	5.0 mg/L (inland) 4.0 mg/L (estuarine)

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Appendix A

Sampling Coverage and Data Evaluation

List of Tables

Table A-1. LDEQ continuous monitoring water quality sampling coverage for reference sites in the Lower Mississippi River Alluvial Plains Ecoregion.

X - Project Number WQ1991006 (Ecoregion)

Subecoregion	Subsegment Number	Site Number	Site Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Eastern	LA040502	3949	Tickfaw River	X	X	X	X	X	X	X	X	X	X	X	X
	LA040403	0243	Blind River east of Gonzales, LA	X	X	X	X	X	X	X	X		X	X	X
	LA040601	3946	Middle Bayou near Manchac, LA	X	X	X	X	X	X	X	X		X	X	X
	LA040403	0156	Blind River at Gramercy, LA	X	X	X	X	X	X	X	X		X	X	X
	LA040401	1102	Blind River near confluence with Lake Maurepas	X	X	X	X	X	X	X	X		X	X	X
	LA040601	0264	Pass Manchac at Manchac, LA	X	X	X	X	X	X	X	X	X	X	X	X
Western	LA120107	0998	Upper Grand River at Levee	X	X	X	X	X	X	X	X	X	X	X	X
	LA120107	3083	Upper Grand River NE of Grand River, LA	X	X		X	X	X	X	X	X	X	X	X
	LA120201	3081	Bay Natchez west of Bayou Corne, LA		X		X	X	X	X	X	X	X	X	X
	LA120206	2976	Grand Bayou southwest of Belle Rose, LA		X	X	X	X	X	X	X	X	X	X	X
	LA120204	3079	Pierre Part Bay southeast of Pierre Part, LA			X	X	X	X	X	X	X	X	X	X
	LA120107	2750	Pat Bay southwest of Plaquemine, LA[1]		X		X	X	X	X	X	X	X	X	X
	LA120107	3082	Lower Flat of the Upper Grand River northeast of Grand River, LA			X	X	X	X	X	X	X	X	X	X

Table A-2. LDEQ fish sampling coverage during sampling events in the Lower Mississippi River Alluvial Plains Ecoregion. E – Electroshock; H – Hoop net; S – Seine.

Subecoregion	Subsegment	Site Number	Site Description	BTUAA 2005-2006	2010-2012
Eastern	LA040502	3949	Tickfaw River		E,H
	LA040403	0243	Blind River east of Gonzales, LA		E,H
	LA040601	3946	Middle Bayou near Manchac, LA		E,H
	LA040403	0156	Blind River at Gramercy, LA		E,H
	LA040401	1102	Blind River near confluence with Lake Maurepas		E,H
	LA040601	0264	Pass Manchac at Manchac, LA		E,H
Western	LA120107	3083	Upper Grand River NE of Grand River, LA	E,H,S	
	LA120206	2976	Grand Bayou southwest of Belle Rose, LA	E	
	LA120107	2750	Pat Bay southwest of Plaquemine, LA[1]	E,H,S	
	LA120107	3082	Lower Flat of the Upper Grand River northeast of Grand River, LA	H,S	

Table A-3. Anomalous data points identified by LDEQ in continuous monitoring water quality data collected by LDEQ. These data points were omitted from analysis.

Subecoregion	Site Number	Sampling Date	Number of Data Points Omitted	Comments
Eastern	0156	3/13/2013	92	Equipment malfunction – monitor redeployed
	0264	12/11/2012	5	Deployment spike
	1102	6/4/2012	282	DO probe failed post calibration
Western	3083	10/15/2012	1	Deployment spike

Appendix B

Habitat Descriptions

Table of Contents

1. Subsegment 040401

1.1. Site 1102 – Blind River

Site Location: near confluence with Lake Maurepas
Parish: Livingston
Subsegment: LA120107
Photos:

Predominant surrounding land uses are forest and wetlands; local watershed erosion is none to slight. Stream shading is open to partially shaded with approximately 0-5% cover. There are no dams present and some natural channelization has occurred. Access to the water body is by boat ramp; evidence of recreational use includes fishermen and boaters. The approximate stream varies from 80 to 200 meters and the approximate run depth is 4.5 to 7 meters. The approximate pool depth is 7 to 10 meters and the high water mark is approximately 0.5 to 1.0 meters. The water varies in clarity from clear to slightly turbid.

2. Subsegment 040403

2.1. Site 0243 – Blind River

Site Location: east of Gonzales, LA
Parish: Livingston
Subsegment: LA040403
Photos:

Predominant surrounding land uses are forest and wetlands; local watershed erosion is none to slight. Stream shading is open with approximately 0-10% cover. There are no dams present and some natural channelization has occurred. Access to the water body is by boat ramp; evidence of recreational use includes fishermen and boaters. The approximate stream width varies from 60 to 200 meters and the approximate run depth is 5 to 7 meters. The approximate pool depth is 7 to 10 meters and the high water mark is approximately 0.5 to 1.0 meters. The water varies in clarity from clear to slightly turbid.

2.2. Site 0156 – Blind River

Site Location: at Gramercy, LA
Parish: St. James
Subsegment: LA040403
Photos:

Predominant surrounding land uses are forest and wetlands; local watershed erosion is none to slight. Stream shading is open to partially shaded with approximately 0-25% cover. There are no dams present and some natural channelization has occurred. Access to the water body is by boat ramp; evidence of recreational use includes fishermen and boaters. The approximate stream width varies from 50 to 100 meters and the approximate run depth is 2.5 to 6 meters. The approximate pool depth is 5 to 10 meters and the high water mark is approximately 1.0 meter. The water varies in clarity from clear to opaque.

3. Subsegment 040502

3.1. Site 3949 – Tickfaw River-

Site Location:
Parish: Livingston
Subsegment: LA040502
Photos:

Predominant surrounding land uses are forest and swamp; local watershed erosion is slight to moderate. Stream shading is mostly open to partially shaded with approximately 15-75% cover. There are no dams present and some natural channelization has occurred. Access to the water body is by road or boat ramp; evidence of recreational use includes swimmers, fishermen and boaters. The approximate stream width varies from 3 to 60 meters and the approximate run depth

is 2 to 4 meters. The approximate pool depth is 3 to 7 meters and the high water mark is approximately 1.0 meter. The water varies in clarity from clear to slightly turbid.

4. Subsegment 040601

4.1. Site 3946 – Middle Bayou

Site Location: near Manchac, LA
Parish: Tangipahoa
Subsegment: LA040601
Photos:

4.2. Site 0264 – Pass Manchac

Site Location: near Manchac, LA
Parish: St. John the Baptist
Subsegment: LA040601
No photos available.

Predominant surrounding land uses are swamp, marsh and wetlands; local watershed erosion varies from slight to heavy. Stream shading is open with approximately 0 % cover. There are no dams present and some natural channelization has occurred. Access to the water body is by boat ramp; evidence of recreational use includes swimmers, fishermen and boaters. The approximate stream width varies from 150 to 400 meters and the approximate run depth is approximately 12 meters. The approximate pool depth is 15 to 20 meters and the high water mark is approximately 0.3 to 3.4 meters. The water varies in clarity from clear to opaque.

5. Subsegment 120107

5.1. Site 0998 – Upper Grand River

Site Location: at levee
Parish: Iberville
Subsegment: LA120107
No photos available.

Predominant surrounding land uses are forest and wetlands; local watershed erosion is slight; stream surface shading is open to partly shaded with approximately 5-10% cover; there are no dams present; natural channelization has occurred; access to the water body is by boat ramp; evidence of recreational use includes fishermen and boaters; the approximate stream width is 75 - 80 meters; the approximate run depth is 2.5 meters; the high water mark is approximately 1 meter; the water is opaque and murky; inorganic substrate is estimated to be 100% silt; organic substrate is estimated to be 100% muck/mud; the low gradient stream habitat rating for the bayou is "fair - good".

5.2. Site 3083 – Upper Grand River

Site Location: northeast of Grand River, LA
Parish: Iberville
Subsegment: LA120107
No photos available.

Predominant surrounding land uses are forest and wetlands; local watershed erosion is slight; stream surface shading is open to partly shaded with approximately 5-10% cover; there are no dams present; natural channelization has occurred; access to the water body is by boat ramp; evidence of recreational use includes fishermen and boaters; the approximate stream width is 75 - 80 meters; the approximate run depth is 2.5 meters; the high water mark is approximately 1

meter; the water is opaque and murky; inorganic substrate is estimated to be 100% silt; organic substrate is 50% muck/mud; the low gradient stream habitat rating for the bayou is "fair - good".

5.3. Site 2750 – Pat Bay

Site Location: southwest of Plaquemine, LA
Parish: Iberville
Subsegment: LA120107
Photos:

Predominant surrounding land uses are forest and wetlands; local watershed erosion is slight; stream surface shading is open with approximately 5% cover; there are no dams present; there is no channelization; access to the water body is by boat ramp; evidence of recreational use includes fishermen and boaters; the approximate stream width is 250 meters; the high water mark is approximately 1 meter; the water is slightly turbid and green-brown in color; inorganic substrate is estimated to be 80% silt and 20% clay; organic substrate is estimated to be 10% detritus and 90% muck/mud; the low gradient stream habitat rating for the bay is "fair - good".

5.4. Site 3082 – Lower Flat of Upper Grand River

Site Location: lower flat of the Upper Grand River northeast of Grand River, LA
Parish: Iberville
Subsegment: LA120107
Photos:

Predominant surrounding land uses are forest and wetlands; local watershed erosion is slight; stream surface shading is open with approximately 5% cover; there are no dams present; no channelization is evident; access to the water body is by boat ramp; evidence of recreational use includes fishermen and boaters; the approximate stream width is 175 meters; the approximate run depth is 1-2 meters; the high water mark is approximately 1 meter; the water is opaque and brown-green in color; inorganic substrate is estimated to be 50% silt and 50% clay; organic substrate is estimated to be 50% detritus and 50% muck/mud; the low gradient stream habitat rating for the river is "fair".

6. Subsegment 120201

6.1. Site 3081 – Bay Natchez

Site Location: west of Bayou Corne, LA
Parish: Iberia
Subsegment: LA120201
(no photos from site visit)

Predominant surrounding land uses are wetlands; local watershed erosion is slight; stream surface shading is partly open with approximately 10% cover; there are no dams present; there is no channelization; access to the water body is by boat ramp; evidence of recreational use includes fishermen; the approximate stream width is 40 meters; the approximate run depth is 3 meters; the approximate pool depth is 4 meters; the water is opaque and murky-brown in color; inorganic substrate is estimated to be 100% silt; organic substrate is estimated to be 50% detritus and 50% muck/mud; the low gradient stream habitat rating for the bay is "good - excellent".

7. Subsegment 120204

7.1. Site 3079 – Pierre Part Bay

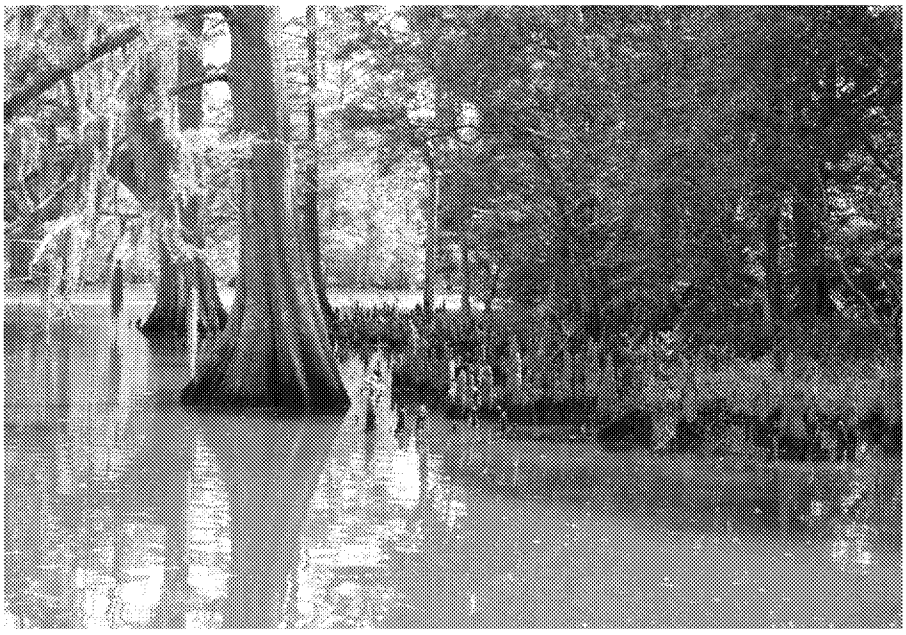
Site Location: southeast of Pierre Part, LA
Parish: Assumption
Subsegment: LA120204
Photos:

Predominant surrounding land use is wetlands; local watershed erosion is slight; stream surface shading is open; there are no dams present; there is no channelization; access to the water body is by boat ramp; evidence of recreational use includes fishermen; the approximate run depth is 6 feet; the approximate pool depth is 8 feet; the bay is slightly turbid and tea colored; inorganic substrate is estimated to be 100% silt; organic substrate is estimated to be 50% detritus and 50% muck/mud; the low gradient stream habitat rating is not applicable.

8. Subsegment 120206

8.1. Site 2976 – Grand Bayou

Site Location: southwest of Belle Rose, LA
Parish: Assumption
Subsegment: LA120206
Photos:



Predominant surrounding land use is wetlands; local watershed erosion is slight; stream surface shading is open with approximately 5% cover; there are no dams present; channelization has occurred; access to the water body is by boat ramp; evidence of recreational use includes fishermen, boaters, and fishing tackle; the approximate stream width is 40 meters; the approximate run depth is 3-4 meters; inorganic substrate is estimated to be 5% sand, 90% silt, and 5% clay; organic substrate is estimated to be 40% detritus, 50% muck/mud, and 10% other organic material; the low gradient stream habitat rating for the bayou is "good".

Appendix C

Water Quality Data Analysis

Table C-1. Summary statistics for all chemical continuous monitoring data collected in the Lower Mississippi River Alluvial Plains (LMRAP) Ecoregion between 2005 and 2012, listed by subecoregion. Data were truncated to 24 hour periods prior to calculation of statistics.

Variable	Subecoregion	Sample Size	Minimum	10th Percentile	Median	Maximum	Mean	Standard Deviation
Dissolved Oxygen Concentration (mg/L)	East	25594	0.2	2.2	6.0	12.2	5.7	2.4
	West	24927	0.2	2.8	5.9	17.4	5.9	2.5
Percent Dissolved Oxygen (% saturation)	East	25536	2.2	26.5	67.4	133.3	64.1	25.4
	West	24827	2.5	35.0	69.2	207.6	69.7	28.6
pH	East	25003	5.4	6.2	6.8	8.4	6.7	0.4
	West	25207	6.6	7.1	7.5	9.8	7.6	0.5
Salinity (ppt)	East	25594	0.0	0.0	0.2	4.9	0.5	0.8
	West	25207	0.0	0.1	0.2	0.3	0.2	0.0
Specific Conductivity (µS/cm)	East	25594	9.0	46.0	328.0	8699.0	990.2	1442.8
	West	25207	0.2	177.0	332.0	527.0	312.2	116.6
Temperature (°C)	East	25594	3.6	10.7	23.9	34.6	21.8	7.2
	West	25207	8.6	14.3	25.9	34.1	24.0	6.7

Appendix D

Biological (Fish) Data Analysis

Table D-1. Fish taxa observed at LDEQ collections in eastern LMRAP reference streams. Species are sorted by rank of abundance; number of occurrences is the number of collections (out of 12 total) in which the taxa was observed; mean relative abundance is the mean percent contribution of the taxa to the total catch of a collection; standard deviation is the standard deviation of this mean; abundance rank is the rank of the mean relative abundance of the taxa (1 = most abundant taxa and 46 = least abundant taxa).

Species Name	Common Name	Abundance Rank (1-46)	Mean Relative Abundance (%)	Standard Deviation (%)	Number of Occurrences (n of 12)
Mugil cephalus	Striped Mullet	1	24.15	20.76	12
Brevoortia patronus	Gulf Menhaden	2	14.73	29.59	5
Micropterus salmoides	Largemouth Bass	3	13.13	15.08	12
Dorosoma petenense	Threadfin Shad	4	7.83	17.40	5
Lepomis macrochirus	Bluegill	5	7.70	8.79	10
Lepomis microlophus	Redear Sunfish	6	5.31	5.46	10
Lepisosteus oculatus	Spotted Gar	7	5.09	5.28	12
Ictalurus punctatus	Channel Catfish	8	3.33	5.51	9
Dorosoma cepedianum	Gizzard Shad	9	2.82	3.32	11
Lepomis megalotis	Longear Sunfish	10	2.45	5.46	6
Fundulus olivaceus	Blackspotted Topminnow	11	1.64	5.55	2
Lepomis gulosus	Warmouth	12	1.12	2.76	4
Lepomis punctatus	Spotted Sunfish	13	1.04	1.72	7
Pomoxis nigromaculatus	Black Crappie	14	0.99	1.21	6
Fundulus notatus	Blackstripe Topminnow	15	0.93	2.77	2
Ictiobus cyprinellus	Bigmouth Buffalo	16	0.85	1.37	6
Notemigonus crysoleucas	Golden Shiner	17	0.74	1.31	4
Micropogonias undulatus	Atlantic Croaker	18	0.66	1.97	3
Labidesthes sicculus	Brook Silverside	19	0.53	1.49	3
Ictalurus furcatus	Blue Catfish	20	0.52	0.79	6
Moxostoma poecilurum	Blacktail Redhorse	21	0.46	1.22	2
Menidia audens	Mississippi Silverside	22	0.44	1.03	4
Cynoscion nebulosus	Spotted Seatrout	23	0.42	1.44	1
Anchoa mitchilli	Bay Anchovy	24	0.37	1.27	1
Aplodinotus grunniens	Freshwater Drum	25	0.36	0.74	5
Amia calva	Bowfin	26	0.35	1.07	2
Notropis atrocaudalis	Blackspot Shiner	27	0.30	1.04	1
Anguilla rostrata	American Eel	28	0.24	0.44	4
Lepomis cyanellus	Green Sunfish	29	0.24	0.44	4
Lepomis humilis	Orangespotted Sunfish	30	0.23	0.62	2
Pogonias cromis	Black Drum	31	0.16	0.54	1
Cyprinus carpio	Common Carp	32	0.13	0.25	3
Paralichthys lethostigma	Southern Flounder	33	0.12	0.36	3
Cyprinella venusta	Blacktail Shiner	34	0.10	0.25	2
Elops saurus	Ladyfish	35	0.10	0.35	1
Heterandria formosa	Least Killifish	36	0.06	0.21	1

Species Name	Common Name	Abundance Rank (1-46)	Mean Relative Abundance (%)	Standard Deviation (%)	Number of Occurrences (n of 12)
Micropterus punctulatus	Spotted Bass	37	0.06	0.21	1
Pomoxis annularis	White Crappie	38	0.06	0.14	2
Aphredoderus sayanus	Pirate Perch	39	0.05	0.14	2
Sciaenops ocellatus	Red Drum	40	0.05	0.18	1
Morone mississippiensis	Yellow Bass	41	0.04	0.13	1
Ameiurus natalis	Yellow Bullhead	42	0.04	0.12	1
Lepisosteus osseus	Longnose Gar	43	0.03	0.12	1
Gambusia affinis	Western Mosquitofish	44	0.02	0.07	1
Polyodon spathula	Paddlefish	45	0.01	0.05	1
Atractosteus spatula	Alligator Gar	46	0.00	0.01	1

Table D-2. Fish taxa observed at LDEQ collections in western LMRAP reference streams. Species are sorted by rank of abundance; number of occurrences is the number of collections (out of 11 total) in which the taxa was observed; mean relative abundance is the mean percent contribution of the taxa to the total catch of a collection; standard deviation is the standard deviation of this mean; abundance rank is the rank of the mean relative abundance of the taxa (1 = most abundant taxa and 39 = least abundant taxa).

Species Name	Common Name	Abundance Rank (1-39)	Mean Relative Abundance (%)	Standard Deviation (%)	Number of Occurrences (n of 11)
Ictalurus punctatus	Channel Catfish	1	42.33	47.28	11
Lepomis macrochirus	Bluegill	2	18.95	20.55	6
Ictiobus bubalus	Smallmouth Buffalo	3	4.06	8.26	5
Mugil cephalus	Striped Mullet	4	3.52	4.09	6
Micropterus salmoides	Largemouth Bass	5	3.00	3.74	6
Pomoxis nigromaculatus	Black Crappie	6	2.81	3.19	6
Dorosoma petenense	Threadfin Shad	7	2.70	3.33	6
Lepomis megalotis	Longear Sunfish	8	2.43	5.91	5
Ameiurus	Bullheads	9	2.29	7.53	2
Lepomis gulosus	Warmouth	10	2.22	3.64	5
Ictiobus cyprinellus	Bigmouth Buffalo	11	1.99	5.51	3
Dorosoma cepedianum	Gizzard Shad	12	1.93	3.20	4
Lepomis cyanellus	Green Sunfish	13	1.72	2.61	5
Cyprinus carpio	Common Carp	14	1.72	2.20	6
Lepisosteus oculatus	Spotted Gar	15	1.48	2.53	6
Lepomis microlophus	Redear Sunfish	16	1.45	2.13	6
Anchoa mitchilli	Bay Anchovy	17	0.71	1.50	4
Lepomis humilis	Orangespotted Sunfish	18	0.58	0.96	4
Lepomis	Common Sunfishes	19	0.56	1.86	1
Pomoxis annularis	White Crappie	20	0.47	0.79	5
Notemigonus crysoleucas	Golden Shiner	21	0.43	0.95	3
Ictalurus furcatus	Blue Catfish	22	0.40	0.63	4
Lepisosteus platostomus	Shortnose Gar	23	0.35	0.73	3
Aplodinotus grunniens	Freshwater Drum	24	0.33	0.50	4
Lepomis punctatus	Spotted Sunfish	25	0.29	0.80	2
Amia calva	Bowfin	26	0.26	0.34	5
Lepisosteus osseus	Longnose Gar	27	0.24	0.81	1
Hybognathus nuchalis	Mississippi Silvery Minnow	28	0.19	0.48	2
Hypophthalmichthys molitrix	Silver Carp	29	0.13	0.43	1
Ameiurus nebulosus	Brown Bullhead	30	0.08	0.26	1
Clupeidae	Herrings	31	0.08	0.26	1
Ameiurus natalis	Yellow Bullhead	32	0.07	0.23	1
Labidesthes sicculus	Brook Silverside	33	0.06	0.21	1
Fundulus chrysotus	Golden Topminnow	34	0.05	0.16	1
Aphredoderus sayanus	Pirate Perch	35	0.03	0.12	1
Pylodictis olivaris	Flathead Catfish	36	0.03	0.12	1
Micropterus punctulatus	Spotted Bass	37	0.03	0.11	1

Species Name	Common Name	Abundance Rank (1-39)	Mean Relative Abundance (%)	Standard Deviation (%)	Number of Occurrences (n of 11)
Morone mississippiensis	Yellow Bass	38	0.02	0.05	1
Anchoa hepsetus	Striped Anchovy	39	0.02	0.05	1

Table D-3. Total abundance (number of individuals observed) and species richness (total number of species observed) in fish collections by LDEQ at reference streams in the LMRAP ecoregion.

Section	Site Name (LDEQ Site Number)	Year	Month	Total Abundance	Total Richness
Western	Pat Bay (2750)	2005	May	5*	2*
			August	4*	2*
		2006	March	564	23
	Grand Bayou (2976)	2005	May	260	22
			August	117	20
		2006	March	141	18
	Upper Grand River (3082)	2005	May	8*	1*
			August	3*	1*
	Upper Grand River (3083)	2005	May	285	21
			August	2*	1*
		2006	March	561	26
Eastern	Tickfaw River (3949)	2010	April	612	20
		2012	October	135	17
	Blind River (0243)	2010	May	239	14
		2012	August	238	18
	Middle Bayou (3946)	2010	May	618	14
		2012	October	305	9
	Blind River (0156)	2010	May	157	17
		2012	August	409	21
	Blind River (1102)	2010	May	230	15
		2012	August	249	14
	Pass Manchac (0264)	2010	May	4383	12
		2012	September	160	13

*Events with a total abundance less than 100 were excluded from summary statistic calculations.

Table D-4. Summary statistics for total abundance and species richness in fish collections at reference streams in the LMRAP Ecoregion.

	Section	Mean	Range		Standard Deviation	Sample Size (n)
			Min.	Max.		
Total Species Richness	Eastern	15.3	9	21	3.4	12
	Western	21.7	18	26	2.7	6
Total Abundance	Eastern	644.6	135	4383	1188.5	12
	Western	321.3	117	564	197.8	6